THE HYBRID BACTERIOLOGIST

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At about the time I was completing my first year of graduate work in chemical engineering, Dr. W. P. Larsen, then Head of the Department of Bacteriology at the University of Minnesota, offered me an instructorship in his department. Since up to that time my training had been limited to chemistry and engineering, with none whatsoever in biology, I was more than a little surprised to receive such an offer, and my first impulse was to reject it. Dr. Larsen, sensing my feeling, assured me that he was aware of my background but that he wanted someone in his department trained in an area outside of bacteriology and said, "We can teach you the bacteriology you need to know but not chemistry and engineering. Further, if we can instill into you an interest in this area of biology, it will be good for you and, in the meantime, it will be good for us to have someone in the department with a different point of view."

For some time, I thought that my unorthodox entrance into bacteriology was unique, but after becoming familiar with the background of others in the field, I found that such an experience is not unusual but rather common.

Most of the pioneers in bacteriology received very little, if any, training in this discipline during their formal school days. Such was certainly the experience of Pasteur, Koch, and most of their colleagues and students. This must have also been true for Burrill, Park, Sedgwick, Welch, and many other pioneers in the field. In a recent letter I received from a well-known bacteriologist who is now retired from active work, he writes as follows: "It may interest you to know that some of us who are old-timers never did receive much formal training in bacteriology. The only bacteriology I ever studied in my college and university days was in a course in botany, where we devoted a short time to this subject."

After examining the background of the staff in our department at the University of Illinois, I found that out of eight full-time staff members, only one received any training in bacteriology during his undergraduate days. Of the others, two came in from a background of engineering, one from training in biochemistry, one from soil chemistry, one from mathematics, one from a medical training, and one from training in general biology. Is such a makeup unusual or is this a common situation in many departments? If this is true, are we in error in many universities in offering rigid programs leading to undergraduate degrees with a major in bacteriology? A prominent bacteriologist recently wrote to me, "I have come to be very strongly of the opinion that microbiology should not be offered as an undergraduate curriculum."

What has been the background training of those who have made the important contributions to bacteriology the past 20 to 40 years? Did they become interested in the science early in their college courses or did they enter the field later from other disciplines? To satisfy my curiosity, I have initiated a limited inquiry into the preprofessional schooling of some of our outstanding men in the field.

First of all, who are these outstanding bacteriologists? I preferred not to trust my own selections since I would be prejudiced by my own interests and acquaintances. A selection made by any other one person would probably not be much better for the same reason. I, therefore, adopted the plan of writing to various departments or selected individuals in some of the larger universities. I asked them to send me a list of whom they considered to be the 20 leading living bacteriologists, those who had in their opinions made the greatest contributions as teachers and research workers. In some cases, these lists were made up by individuals but usually they were the combined opinions of several persons in the respective departments to which inquiries were sent. I received excellent cooperation in that, out of twenty, only one failed to respond.

From these, I selected the ones who appeared on 15 per cent or more of the lists and found that there were in this group 43 names. I sent a letter to each of the 43, inquiring about his background training, when he became interested

in microbiology, and his opinion as to how students should be trained for this work in the future. The following is a resumé of the information obtained. Here again, I was fortunate in getting a very good response. To date, 35 of the 43 have responded to my request, and others may probably do so later.

Thirty per cent of this group became interested in microbiology after they had obtained their Ph.D.'s or equivalent graduate degrees. Thirty-eight per cent became interested in the field during their graduate training, 18 per cent when they were seniors in their undergraduate work, and the balance, or 14 per cent, at an earlier date, either during their sophomore or junior year. Thus, 68 per cent of this group did not receive training in bacteriology during their undergraduate years.

Among this group of prominent men, there has been a great deal of variation in their interest and training prior to the time they became interested in microbiology. The largest group, 39%, was trained in some branch of chemistry, principally organic or biochemistry, while 14 per cent received their early training in engineering. Seventeen per cent each in botany and medicine, three per cent in physics, and only three per cent of the group started their college training with the intention of becoming bacteriologists. The remaining seven per cent came from a variety of other backgrounds. It can be seen from this that most of these men were attracted to a discipline dealing with quantitative measurements.

Concerning the extent of training they had received in the various branches of science, the following data are of interest: Fifty seven per cent received training in chemistry beyond one year of organic; the additional training consisted usually of advanced organic, biochemistry and/or physical chemistry. Twenty three per cent studied chemistry as far as one year of organic but not beyond, and the remaining 20 per cent had less. Thus, about 80 per cent had training in chemistry equivalent to at least a year of general inorganic, quantitative and qualitative analysis, and a year of organic.

Twenty per cent of the group received training in mathematics beyond one year of calculus. Another 60 per cent had a year of calculus, including integral and differential. Only 10 per cent of the group received no college training in mathematics and another 10 per cent took some mathematics, but short of calculus.

The information received was not sufficiently detailed to permit a similar analysis of the extent of training that this group had received in physics, biology, languages, or the humanities. Such information would be interesting and instructive, but I hesitated sending out a sufficiently elaborate questionnaire to permit this tabulation.

In response to questions from this group as to the extent of training they believed the future students of bacteriology should have, 65 per cent recommended training in chemistry beyond one year of organic. An additional 25 per cent stated that chemistry as far as one year of organic was the minimum to be required. Thus, only 10 per cent of the group did not stress training in chemistry.

Seventy-seven per cent of the group recommended training in mathematics to include a minimum of one year of calculus, while 23 per cent did not emphasize this need. Many stressed the need for a more thorough training in genetics than has been customary in the past, as well as a more general knowledge of biology and statistics.

The above observations agree, in general, with those arrived at by Dr. Evans and his committee, who made a careful survey of desirable undergraduate curricula for the training of bacteriologists. After conferring with many departments and individuals, this committee concluded that bacteriologists in the future should be trained in chemistry to the extent of at least one year of organic, a year of college physics, and a year of biology exclusive of courses acceptable as microbiology. In addition, this committee recommended courses in mathematics through calculus, physical chemistry, statistical methods, biochemistry, and genetics, and courses aimed at improving verbal and written communications.

In many departments, the question must arise whether or not there should be an undergraduate curriculum in bacteriology and, if so, what should be the minimum requirements. Furthermore, in such a program should the department be concerned with the training of scientists or technicians? It is certainly true that with an expanded interest in bacteriology by industries and private and public research laboratories, there is a great demand for persons

with technical training to serve as technicians or assistants in bacteriological laboratories. A desire to fulfill this demand and to build up a larger enrollment in bacteriology has, in some departments, diverted the attention from training of scientists to the training of technicians. Very often the size of the staff and the operating budget is predicated upon the number of students taking courses in the department. This serves as a powerful incentive for extensive course offerings and for the encouragement of students to take courses in bacteriology rather than in other areas of science, or offerings in the liberal arts.

In recent years there has been a great demand for students having bachelor's or master's degrees with a major in bacteriology, and bacteriology departments are certainly rendering a valuable service to the country by training people to fill these positions. However, we must not lose sight of the fact that many of the students entering such a program may become sufficiently excited about bacteriology to go on for graduate work. Therefore, I believe the training received should be suitable as preparatory work for a graduate program. This conflict of purpose in the training of technicians on the one hand and the training of scientists on the other should be resolved in favor of an undergraduate program that stresses fundamentals with just sufficient bacteriology to permit the student to become a useful citizen as a technician, if a bachelor's degree is to be the extent of his formal schooling. If he has received training in chemistry, physics and mathematics, he should be more useful in whatever laboratory he is working or on whatever problem he is assigned than if he devoted most of his technical training to bacteriology only. It is my conviction that it is a mistake for a university department to put major emphasis on the learning of skills. That should be incidental to a more fundamental approach. If it is necessary to have a certain number of students to justify the budget and the staff, that had best be attained by offering suitable, useful, and interesting service courses to fill the need for some training in bacteriology to students majoring in other fields. However, as for the training of future bacteriologists, it is more important to emphasize quality than quantity.

It must be borne in mind, when we consider graduate training that, as has been pointed out earlier, a large percentage of persons who are successful bacteriologists today did not enter the field until they were in the graduate school or later. We should expect, therefore, that many of our graduate students will come to us with little or no training in the field in which they want to specialize. Today, with the very high cost of living and with the numerous fellowships that are available for talented students, it may not be easy to attract such students into bacteriology from other areas.

In most departments it is common practice to subsidize graduate students by offering them part-time teaching or research assistantships. For the department to function efficiently, however, the former positions must usually be reserved for those who have had previous training in the area. Graduate students who come to us with little or no training in bacteriology must, therefore, be subsidized by some other means. A portion can be taken care of by fellowships from the National Science Foundation or other government agencies or with scholarships offered by the various universities. In general, however, most students who apply for such aid will plan graduate study in the area in which they have had previous training. If we are, therefore, to attract them into our field, a new source of funds for special types of support must be found. Also better methods of communication must be developed so that prospective students from other areas will be aware of the opportunities that are available to them in this new field. In particular, we need to contact the small liberal arts colleges where students often obtain an excellent education but where they have had no opportunity to become familiar with this area of biology. However it may be done, it is important for us to make provisions for graduate students who come to us with no previous training in biology but with good training in other areas. It is quite likely that these will ultimately be among our most promising students.

It was also pointed out earlier that a fair percentage of the bacteriologists who are making important contributions to the science did not enter the field until after they had received their Ph.D. or equivalent degrees. This emphasizes the importance and the necessity of providing opportunities for post-doctorate training. Any forward-looking department must, therefore,

make provisions for visiting scholars who can join the staff of a department as research associates. Here they can learn bacteriology by working with microbiologists, and they can participate in those courses that are of interest and value to them. Such persons are, of course, generally older than ordinary graduate students, very often married, and have family responsibilities. Therefore, they must be provided with a higher level of support than is necessary for the average graduate student. The affiliation of such persons with the staff of the department is, however, no one-way benefit. The visiting scholars will profit by having an opportunity to learn a new discipline, but their presence will also bring new ideas into the department. In any scientific group it is desirable to have a certain critical mass of competent persons for mutual activation. Thus, these visiting scholars will help the average department attain this needed critical mass.

So far, we have concerned ourselves primarily with the technical education of the microbiologists, but there are other areas that need to be stressed as well. In one of the answers received to my inquiries, the writer made the following statement: "There is a deplorable world-wide tendency for people to become microbiologists without an adequate and genuine general education." He further stated that in his country a meeting of microbiologists was conspicuous by the low level of education among its members. Whether or not you agree with this statement, I think you will all agree that in this day of world tension, with dangers of wars that can annihilate the entire civilization, it is important that our trained people know something other than their own narrow specialties.

Furthermore, because of our modern means of travel, the world has shrunk to the extent that it is no more unusual for the average person to attend conferences in Europe than it was in earlier years for a midwesterner to attend a convention in this city. In conversations with fellow scientists today, it is common to hear that your visitor is planning either to attend a conference in Europe or has recently been there. Such personal contacts with scientists in other countries can contribute materially to a broadening of our knowledge. Not only does it give us an opportunity to understand each other better, but also it emphasizes the importance of a broader education, particularly the history, culture, and languages of other people.

Last year, when I attended a conference of microbiologists in Lille, France, I was impressed by the ability of the European scientists to converse freely with each other in two or three languages. In America, we have stressed the need of some knowledge of foreign languages in the Ph.D. program, requiring the candidates to pass reading examinations in French and German. However, we will all admit that for most of us this has been a very superficial knowledge. With an ever increasing opportunity for international meetings, it is now more important than ever that our future scientists become more familiar with and better able to converse in at least one foreign language. This appears to be a terrible task for our American students, but I strongly suspect that this is not due to faulty methods of teaching but rather to a lack of appreciation of need and a lack of will to learn.

It has been my thesis that bacteriologists, whenever possible, should be persons with dual training, and it appears that a large percentage of men and women who have made important contributions to the field are precisely that. Perhaps this is not limited to bacteriologists but true of all scientists in general. Certainly the advantages to be gained are so great that we should encourage students to follow this course whenever possible. Unfortunately, at least so I think, the combinations have been practically always confined to different branches of science. Now, however, because of the new position of responsibility scientists occupy in society today, we should encourage combinations in areas of learning outside of the physical and biological sciences, such as the humanities, the social sciences, and the languages and cultures of other people.

During the period of the renaissance it was the theologian who spoke with authority and was listened to and respected by the people. At an earlier date the philosopher held that position. Today, the scientist, whether he wants to or not, occupies this role and with it goes a great responsibility—some would say a terrible responsibility.

Today, when a scientist speaks, the public will listen and believe whether they fully understand what is said or not and, because they do not understand, often they draw conclusions

that were not intended or justified. Furthermore, if the scientist himself is a man with a limited general knowledge, he may not be aware of the implications his statement may have on other walks of life. I am reminded here of a quotation from the writings of Thomas Huxley: "If a little knowledge is dangerous, where is the man who has so much as to be out of danger?" In this day of expanding knowledge no one can be informed in all areas. We cannot even be expert in several fields, but as an alternative, we need not as a group become too isolated or insulated from others, if some of us will acquire a dual training with one discipline outside of science.

In any event, let us not discourage students in these areas if they want to change their specialty to bacteriology, but rather let us encourage them to continue to broaden their knowledge in the former field while they are learning the new one. The hybrid from bacteriology and the humanities or from bacteriology and the social sciences may be as fruitful as has been the hybrid from bacteriology and the other sciences. In selecting graduate students, we should, of course, be concerned with their mental capacity, but let us not make the mistake of assuming that a mere accumulation of scientific facts is necessarily a criterion of mental prowess.

I have stressed the importance of a training that involves more than one discipline, but let us not overlook the fact that there have been a number of bacteriologists who have made very important contributions without having had such a hybrid education. In addition to the "bacteriologist-chemist," the "bacteriologist-engineer," and the "bacteriologist-physicist," there is also room for the "coliologist," the "lactobacteriologist," or any other person who is highly specialized in a small group of organisms with limited interest or knowledge of other groups. In this I am certain that our past president, Dr. van Niel, will not object if I quote him in this regard. "Though it often seems to me that a sound acquaintance with many types of these organisms through firsthand experience is very desirable, so that fundamental training in mycology, algology, protozoology, and 'general' bacteriology would be required, I am also willing to grant that 'specialists,' who know profoundly only a single group or type of bacteria, can make contributions of so fundamental a nature that it would be hard to justify the conclusion that they should have been 'better bacteriologists' had they been subjected to a broader training. I am here reminded of a statement of a Dutch prose writer who wrote, 'The ideal is to be great and good; but I fail to see that it is better to be merely good than to be merely great.' "